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GOVERNMENT RESEARCH, THE ENGINEER, AND THE PROFESSIONAL SOCIETY

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by I. E. Garrick*

In keeping with the general theme of this meeting (namely, the articulation of engineering education with professional societies), I have chosen to discuss the topic: some factors affecting the interaction of government research, the engineer, and the professional society. After much consideration and pondering of the topic for a possible fresh approach, and wondering how I was self-mesmerized into this position, I have come to the conclusion that my real message relates to the current need for continuing education and to the achievement of ways and means for the continuing process of learning. Drawing to some extent on my experience in over 30 years of government research at NACA (predecessor of NASA) and at the National Aeronautics and Space Administration, Langley Research Center, I hope to indicate that the University, the Federal Government, and the Professional Society have primary roles, respectively, in basic foundations, advanced concepts (achieved through research and development), and communication, all of which support "continuing education."

Let it be stated at once, however, that there are mutual interests and needs so that the roles of each overlap. Moreover, many thorny and vexatious issues arise thereby, issues that concern, for example, the proportion of teaching and research, or of consulting and research; what is basic or obsolete in the curriculum; the roles of basic and applied research; the merits of the argument "publish or perish;" the coping with the retrieval of information and with the information explosion, support of education by government grants and contracts or by private funds; what roles of professional societies serve the goals of education; and what are the obligations of a professional man to himself, to his profession, and to society. Obviously, we will not supply answers to these issues, but merely note that there are harmful as well as beneficial elements on each side, hence a proper balance in each sphere is a delicate matter. With these precautionary thoughts in view, let us proceed to develop our topic, within a framework of NASA and, in particular, Langley's educational programs.

It may be appropriate, as this is the anniversary of Thomas Jefferson's birthdate, to repeat a remark of President Kennedy. At dinner at The White House for distinguished scientists, largely Nobel prize laureates, President Kennedy stated that never had The White House entertained so distinguished a company at dinner, since the time when Mr. Jefferson dined there alone.

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The day has long since set when a single man can be versatile or universal in many disciplines or even across the entire spectrum of a single discipline. Our technological society in this age of science is an extremely complex one, full of checks and balances, while at the same time undergoing change at the most rapid rate in history, characterized by a boiling and fulminating technology. Research and development has been the fastest growing category of the federal budget for several years and represents more than 15 percent of the national budget. Aside from national defense and fixed charge parts, it is the greatest part of the budget. Applied research and development of over $18 billion annual rate in the nation is the chief catalyst for our industrial development; 80 percent is underwritten by the federal government against 20 percent by private industry. Of every 10 engineers in the United States, three are in research. We have grown into an age of bigness, big science, big engineering, and big systems - systems whose costs range to hundreds of millions of dollars. The systems are not limited to the military alone, such as long-range bombers, ballistic missiles, or nuclear submarine fleets, but also include a wide range of peaceful endeavors, such as high-energy accelerators for basic research in physics, a national highway system, a supersonic commercial transport, telescopes for radio astronomy, and, of course, the space program with its earth satellites, probes to the moon and planets, and the landing of a man on the moon and returning him safely to earth.

It is a fact of life and a necessity that the team of scientist-engineer-technician is inherent in our advanced technology. The ivory-tower concept of the pure scientist is today largely a fiction. With all due homage to the significant isolated cases of the lone-wolf scientist, more than ever these days he also needs a sounding board, interaction with other workers. We are, all of us, standing on the shoulders of other generations, but today we are on the shoulders of our own contemporaries. Even astronomers are now among the most gregarious. It is fortunate that the techniques and methods of modern science can be put to good use by so many of the not-quite-genius but-merely-competent variety of individuals. (Of course, certain well-known pitfalls of teamwork must be guarded against by enlightened management, as the dilution of personal responsibility and the lack of a suitable environment for individuals of certain anti-team temperament, but with ideas, curiosity, and imagination.)

As well expressed by J. R. Oppenheimer*, science and technology are symbiotic. "Technology gives back to science a rich reward in new instruments, new techniques, new powers. Some of the largest questions that today agitate our curiosity and wonder relate to the disposition and motion of the remotest nebulae, billions of light years away. For evidence on this we look increasingly to radio astronomy, which is based on microwave techniques largely developed for military purposes during and since World War II. Chemistry and biochemistry are able to put and answer questions not only of structure but of dynamics, because they have available the neutrons and tracers which in large measure are a byproduct of the industrial and military development of

* Symposium on Basic Research, American Association for the Advancement of Science, 1959, p. 10

nuclear fission. It is this incessant feedback and reciprocal fertilization which makes a sharp distinction between pure science and technology academic and dreary. There is also an important traffic, not only in ideas and in equipment and in techniques but in men, between the two a traffic without which both would be the poorer."

An important implication of the rapid changes in technology and to the compression of the time interval from generation of ideas to their exploitation in applications, is the corollary that if our standard of living, or at least its index, is to continue to rise, the explosion of technology must increase faster than population. The inferences are that an individual's academic education will no longer serve him adequately through his active career, but will, unless constantly renewed, become obsolete several times over during his working life. Thus, the statement is sometimes heard that the engineer's professional half life is about ten years, or that the average engineer will need to be "retreaded every ten years."

This statement is obviously meant to apply to specialized education rather than to basic foundations; for, I believe that the chief purpose of formal academic education is to stress fundamentals and by emphasizing basic foundations to develop the processes of self-reasoning, self-criticism - in short, self-education potentially to free the student from the teacher for his life-long process of education. Life is too short to achieve this goal efficiently by one's self; hence, the need for higher education, and one of the main functions of banding into professional societies. Indeed, the retraining and refreshment of graduates in maintaining, improving, or augmenting skills is an important function and activity of universities; the federal government and the professional society also have roles to play in this process.

Before describing next a few of the current educational programs of NASA and of the Langley Research Center, in particular, that bear on these matters, a remark on a few odd contrasts with earlier days may interest you. When I came to work at Langley as a junior physicist in 1930, the NACA, charged by Congress to undertake "the scientific study of the problems of flight with a view to their practical solution," had a total number of employees around 250 and a total personnel and expenses budget of about $500,000. It was an energetic group, stimulated by an exciting new field advancing on a boundary between science and engineering, tempered by the raging economic depression. We did our own computing then with slide rule and log tables. I recall that in the 1930's the famous British engineer, F. W. Lanchester, introduced "potted logarithms," a 4- to 8-page document (now obsolete) that sold for 1 shilling. These are not "stewed" logarithms, but a scheme based on practical interpolation principles for computation, whereby these few pages plus a slide rule could do all that a 700-page book of 7-place logarithms would do. Lanchester was an extremely versatile scientist and engineer. First he, and then Ludwig Prandtl, gave the fundamental ideas for the span loading of a wing and the trailing vortex flow picture that accounts for induced drag. It is odd that Lanchester is always called an engineer, while Prandtl is termed an aeronautical scientist; perhaps this is so because Prandtl was a better mathematician.

The big computers which have evolved since around 1950 have transferred ingenuity in other directions (Langley, incidentally, was one of the first to have the relay-type Bell machine, predecessor to the high-speed types), and have become so much a part of the scenery that we speak of the "computer age" and the road to self-regulatory, self-organizing and adaptive systems - that is, to automation. They have an enormous role in space, as witness the real time control of a manned satellite, or use in travel to the moon.

The goals of our large aeronautical and space programs, for which NASA is investing at the rate of over $5 billion a year, serve as focal points, domains of excitement for advancing scientific and technical disciplines. The size of these programs and their interaction with industry and universities are evident from these statistics.* More than 90 percent of NASA's aerospace work is performed under contract with industry. The aerospace program employs approximately 80,000 engineers and scientists. Of this total, 12,000 work inside ten NASA Centers and at NASA Headquarters in Washington, D.C. The remaining 68,000 are employed on NASA contracts and grants. The total represents about 5 percent of the estimated million engineers and half-million scientists in the United States. This vast program can be achieved only by using and developing the superb resources which exist within the Nation's industrial and educational world. Governmental in-house activity is directed toward the conduct of research for which existing federal laboratories have a special competence and to the supervision, integration, and administration of NASA contracts. Obviously, we must maintain a competence within our own organization to insure that NASA's missions are accomplished with the effective use of available resources and the maximum assurance of timely success.

Two out of three NASA technical employees are educated as engineers. The predominant degrees are obtained in mechanical, electrical, and aeronautical engineering which represent, respectively, one-third, one-quarter, and one-fifth of the total of engineers. Those trained in mathematics and physics make up most of the remainder of the NASA staff. About 2 percent are chemists and 1 percent are trained in the life sciences.

The increased requirements for scientists and engineers in this decade from 1.3 million in 1960 to 2.1 million in 1970, as estimated by the National Science Foundation, are expected to result from continued economic growth, expanding research and development activities, exploitation of the resulting discoveries, and the growing complexities of new products and processes for civilian and military use. It is interesting to note that the Saturn-Apollo-Moon program in the remaining sixties will require participation of an estimated 20,000 companies and 300,000 people. There are 5,000 major industrial firms actively working on various phases of this program at the present time.

* "The Engineer and Government Policy," by F. L. Thompson, presented to ASEE at Rutgers University, May 1964

The in-house effort is largely concentrated among the 12,000 employees in the Marshall Space Flight Center in Alabama and at the Manned Spacecraft Center in Texas. Scientific and engineering support of this program is supplied by some of the effort of the NASA Research Centers, of which Langley is one. The Research Centers concern themselves with other significant aerospace projects, among which the Supersonic Commerical Air Transport now stands out, and, of course, with conceptual and early phases of future programs. NASA has recognized from its formation and from its Charter the need to tie our unique university resources into its advanced research and technology programs. A significant portion of the Nation's university complex is involved in the NASA program, concerning itself not only with problems of manned space flight, but also with a more accurate description of the space environment - the moon, the near-earth planets, and the complex solar-terrestrial relationship.

The large impact on and numerous contacts of NASA with educational institutions have been the subject of a recent three-day NASA Program Review Conference at Kansas City, attended by over 600 educators. It will suffice here merely to indicate the scope of these programs. Costs of these programs are currently around $120 million. Some 200 universities are participating. The programs include hundreds of individual grants for research, traineeships for undergraduates, graduate programs having a goal of producing nearly 1,000 Ph.D.'s each year, many multidisciplinary grants for support of basic research, summer institutes, space-flight experiments, grants for research and laboratory facilities. These programs were frankly reviewed with very favorable approval of the audience. When available in published form, I am sure you will find the full proceedings of this meeting most interesting.

Coming closer to my own experience and contacts, I would like now to concentrate more directly on educational programs of the Langley Research Center, especially in relation to contacts with professional societies. Langley has found it necessary to establish and maintain continuing educational opportunities for the staff across a broad front. It is the policy of NASA to encourage engineers, scientists, and other professional staff members to increase their capacity for research by participating in employee development programs. A total of about 500 professional employees, one-third of the professional staff, are enrolled in the Langley Research Center's graduate education program, pursuing advanced studies in programs conducted in cooperation with some 20 colleges and universities. In particular, the Virginia Associated Research Center (VARC) comprised of the College of William and Mary, University of Virginia, and Virginia Polytechnic Institute, is beginning to play a significant role in these programs.

As engineering research and practice encompass new fields, the interface for graduate training between the classroom and practice becomes more difficult. What schools can afford expensive arc jets, cyclotrons, specialized wind tunnels, magneto-plasma facilities, large computers, etc.? The medical doctor moves into a hospital for internship and practices on people. Where does the engineer come to grips with his problems before he practices? Because of its proximity to Langley, VARC has the opportunity to do something about these problems, and some of the concepts suggested for VARC involve the

bringing of graduate engineers into close contact with major facilities, adjacently located or a few miles away, at Langley during their graduate education, and during work on research problems. This mechanism not only strengthens the Research Center, but by regular turnover to industry furnishes a hard core of personnel technically competent.

Langley has also a cooperative engineering program, a highly successful one, that combines alternate work and college-residence periods for undergraduates seeking degrees. The more than 100 participating employees are attending colleges and universities in the area east of the Mississippi River. To round out our interest in the education of the scientist-engineer-technician team, we have an accredited apprenticeship program initiated over 20 years ago that has been an important factor in the development of skill and knowledge required to keep shop methods and techniques abreast of demands of advanced research. It is of significance that of over 600 graduates of this apprentice school about 500 are still working for NASA in numerous trades and skills. All these programs have been of inestimable value also in recruiting and retaining a competent staff.

It is appropriate to mention the ASEE-NASA Summer Faculty Fellowship program which was initiated by several NASA Centers last year and which is being expanded and continued this summer. This is a 10-week summer program for the mutual benefit of young university faculty members and NASA for cooperative research and instruction. The official leaflet states these objectives: (1) To further the professional knowledge of qualified engineering and science teachers, (2) To stimulate an exchange of ideas between participants and NASA, and (3) To enrich and refresh the research and teaching activities of participants' institutions.

The policy of obtaining services of specialist lecturers-consultants for periods of one or two days to one or two weeks has been greatly liberalized in recent years. These arrangements are much appreciated and widely used by the staff. Also greatly liberalized is the representation of Langley staff at specialized summer courses given by various universities.

The practice of many universities to offer specialized courses of current technical interest (generally without academic credit) for periods of one or more weeks during the summer is, in my opinion, an important aspect of continuing education. The practice has existed for teachers for a great many years, but for the benefit of refreshing technical and scientific people in industry and government, I believe, it is relatively new. Among the leaders have been Massachusetts Institute of Technology, the University of Michigan, and the University of California. Clearly, these courses must change with the times and need overhauling almost annually. At Langley we take advantage of the opportunity of enrolling several staff members in such courses each year.

The summer programs in space sciences which Virginia Polytechnic Institute has nurtured successfully at Blacksburg for the past several years have also been noteworthy. Langley has actively participated in these programs by supplying speakers and as a co-sponsor.

A consequence of the forced technological growth that characterizes the space age is that science is developing so rapidly and producing so much information across a broad spectrum of activity that there inevitably is a delay in getting the data into the hands of those who need them. This emphasizes the need for engineers and scientists to maintain close liaison, supplementing published information with conferences and other personal contacts that help fill the gap between the collecting and dissemination of scientific data. This ability of the scientist and engineer to communicate is perhaps the real key to the success of the team concept and to the maintenance of an enlightened, highly competent corps of professionals, whether in or out of government service.

There is a clear obligation to communicate, report, and disseminate significant research results promptly and efficiently, and this is especially true for costly research to avoid unnecessary duplication. Besides its own system of varied reports, NASA encourages publication in recognized journals, many of which are journals of professional societies. A few statistics of my own Division on its interaction with professional societies by talks and papers during the past year may be of interest. The Division has about 105 professional engineers engaged in research and development in areas of Acoustics (noise), Structural Dynamics, Aeroelasticity, Landing Dynamics, and Vibration. More than 65 contributed papers or talks to professional societies, some jointly authored, were given, as well as about a dozen seminars at universities. There were six papers presented at international conferences, ranging geographically from India to Bulgaria. (Among the societies represented were: Acoust. Soc. of America, SAE, ASCE, N.Y. Acad. of Science, AGARD, AIAA, Virginia Acad. of Science, ASME, ASChE, ASTM, IES, AMS, AGU, etc.) In addition, there is representative attendance at specialist meetings without the requirement of a presentation.

A vexatious problem is the multiplicity of meetings on the same or similar topics. This has come about prominently in recent years by the overlapping of disciplines, the big systems of current interest, and the various interfaces and competition among societies. With the overlapping of meetings and topics and with the general tightening of all costs, the problem of retaining essential government and industry support for attendees is becoming much more difficult. The problem is being recognized and slowly remedied by the holding of jointly sponsored meetings. It has probably been a chief factor in the amalgamation of several societies, e.g., the American Institute of Electrical Engineers and the Institute of Radio Engineers into the Institute of Electrical and Electronic Engineers, and the Institute of Aeronautical Sciences and the American Rocket Society into the American Institute of Aeronautics and Astronautics. Still, there is much overlap, e.g., in the field of research on problems of vibrations, with special meetings by the American Society of Mechanical Engineers, the Acoustical Society of America, the American Institute of Aeronautics and Astronautics, the Institute of Environmental Sciences, and

the Shock, Vibration and Associated Environments Symposia initiated by the Office of Naval Research (jointly sponsored and now called the Shock and Vibration Information Center), to mention only part of the story.

Professional societies generally have goals related to 1) advancement of the status of the profession (like a union); 2) advancement of the state-of-the-art through publications, (a) research or technical, (b) trade or product; and 3) meetings (technical and social objectives).

Meetings are of several types: they may be sectional, national, or international; of a broad spectrum covering many diverse technical areas, or devoted to a single technical discipline, a specialist type meeting, also partly tutorial. There is also the device of meetings devoted to technical problems related to a particular large-scale mission or project. The American Institute of Aeronautics and Astronautics lists some 36 technical committees having a total of over 600 members among them. Continuing education is the aim of many technical meetings held at the national level. For example, AIAA in 1964 held 25 such meetings, of which nine were held jointly with other societies; over 1,600 technical papers were presented during the year.

Some statistics on a forthcoming International Specialist Meeting on Structural Dynamics at Cambridge, Massachusetts, in which I am involved, may be of interest: 122 technical papers have been received, 72 from industry, 15 from government agencies, 22 from universities, and 13 foreign. (Of the 22 from universities, only one is from the Southeast.) Only one-third of the total can be accepted for delivery in the three-day meeting if simultaneous sessions are to be avoided.

AIAA is planning, I am told, many (7) regional student conferences this year. Outstanding students from about 90 student branches will gather in the regions for paper presentations, inspection tours, social contact with industry members, and for similar benefits. I cannot speak first-hand, as many of you can, on how these student affairs turn out. They are obviously of advantage to the parent society in assuring turnover, and it is likely they are beneficial to many students. My mental reservations would relate to early exposure of the student, say, before his senior year, and to the diversion of building of superstructure before foundations in education have been set.

It is to be noted that a successful large professional society is of necessity a complex organization. There is thus a tendency toward bureaucracy with its attendant virtues or faults; it is essential for the membership to prevent this tendency to lead to stagnation or to taking over completely to the detriment of the technical side, if the society is to thrive on the technical level. All too easily can the social and business ends of a society become ends in themselves. It is interesting to note that of the AIAA membership of over 36,000, only about one-fourth actually subscribe to the main technical journal (Journal of the AIAA), and only about one-tenth of the membership or less subscribe to the new engineering journals (Journal of Spacecraft and Rockets, and Journal of Aircraft).

One of the important tasks for universities to undertake more systematically than they do is, I believe, seeing to it that by the time a student graduates he knows how to give a crisp, clear technical talk. Journal clubs or student-member clubs or seminar groups with proper guidance or self-criticism can possibly serve this end. One is continually disappointed at professional meetings by the small percentage of really good papers, but mostly disappointment ensues from poor presentations, for even ordinary papers can be useful or tutorial if well presented. At Langley, we generally feel that when a man offers a paper, both his own reputation and that of the organization is put on the line and that it is the obligation of a supervisor to help to see that the paper and the man are ready for effective delivery. I would like to believe that a similar obligation exists at departments of a university towards their representatives, whether student or faculty. In this way the universities can certainly help the professional societies to improve the impact of their technical meetings.

The requirements of a good technical talk are easy to put down, but difficult to realize - clarity, brevity, relationship, novelty, quality for both oral and written presentations, availability of preprints; especially important are readable slides and illustrative material designed to enhance the oral presentation.

It is common knowledge that meeting places are also market places for recruiting for industry and universities. A worthy use of attendance at such meetings of interest for graduate engineering is the soliciting of outstanding individuals or outstanding talks for "repeat" performances at university seminars. I think universities could make more effective use of such opportunities than they do. It remains unfortunately true that despite the multitudes of papers, there is still a great shortage of good papers at practically all meetings and that the educational influence of societies, while potentially strong, is still relatively weak.

An extremely interesting and significant development on the horizon for engineers is the current establishment of the National Academy of Engineering, somewhat parallel to the National Academy of Sciences and starting in close collaboration with it. The NAS, in its capacity of advising the government, frequently has not been in a position to assess realistically the engineering phases of scientific and technological programs. These parts of the big system programs have been the most costly ones, and there has ensued the recommendation of NAS to form the National Academy of Engineering. It is likely that this new Academy will have major influence on government research, graduate engineering, and professional societies, and indeed, on the technological growth of the Nation as a whole.

In bringing this paper to a close, I wish to state that I have enjoyed the opportunity of collecting my own thoughts on these varied topics relating to continuing education, as well as the opportunity and excuse to read the views of many prominent individuals and committees that have written about them. I am convinced that, amidst the delicate and thorny possibilities ahead, the paths of continuing education, in which knowledge is tempered by experience, by creativity, and by wisdom, remain the sure paths to our Nation's growth and survival.

NASA-Langley, 1965